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Field Wilt (*Fusarium*) of Potatoes

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SUGGESTIONS FOR CONTROL

Since the organism causing field wilt is common to Montana soils, it is unreasonable to expect a crop entirely free from the disease.

Seed treatment is not beneficial because the fungus lives within the tuber.

This disease can be reduced to a minimum by maintaining the seed plot and consistently roguing it, thus securing seed of the highest quality.

In the control of this disease a system of crop rotation that will last from three to six years is recommended.

Field Wilt (*Fusarium*) of Potatoes

OCCURRENCE

This disease has been known under various names such as stem blight, fusarium blight, fusarium wilt, or stem-end browning, but the name most commonly accepted at the present time is fusarium wilt, which is rather distinctive of the advanced stages of the disease. It is generally distributed throughout the United States wherever potatoes are grown on a commercial scale. In Montana it occurs universally and can be found in nearly every potato field of commercial importance, varying in quantity from a trace to 15 per cent or more.

ECONOMIC IMPORTANCE

In California wilt is the principal factor limiting the production of potatoes in the famous delta district of the San Joaquin Valley. Haskell (6)* reports considerable loss in the Hudson River Valley and notes the decreased acreage planted to potatoes over a series of years.

It is estimated that fusarium wilt caused a loss of 4 per cent to Montana growers in 1917, which was considered a normal year. McKay (9) illustrates with a map and graphs the losses due to *Fusarium oxysporum* in the western states of Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, and New Mexico. The average loss was 14 per cent, amounting to more than six million bushels. Idaho sustained the greatest loss, amounting to 30 per cent.

This loss is the result of several factors, the most important of which may be enumerated as follows:

1. A certain percentage of plants is killed outright, indicated by missing hills which decrease the yield proportionately.

2. Early death or maturity of affected plants results in decreased yields. Estimates have been made showing that affected plants yield in marketable tubers only about one-third as much as normal plants.

*Figures in parentheses refer to Literature Cited at the end of the bulletin.

3. The discoloration of the stem end, which often is associated with the disease, lowers the market value of the tubers and, if they are sold, causes discontent and dissatisfaction to the purchasers. This often results in a market depression and a consequent financial loss to a district as a whole.

4. Diseased tubers are not suitable for seed.

5. The cooking quality is impaired; if used for home consumption, there is considerable loss in paring and the tubers often become discolored and soggy in the cooking process.

SYMPTOMS OF FUSARIUM WILT

The distinctive characters of the disease are wilting of the leaves, yellowing and premature death of the foliage, and the presence of the fungus in the roots, in the lower part of the stem, in the stolons, and frequently in the tubers. As the fungus can be detected only by microscopical examination, external symptoms must be used for diagnosis in the field.

The time of appearance of the disease varies, depending upon the severity of infection, the age of the plants, and the variety. If diseased stock is used, there is sometimes de-

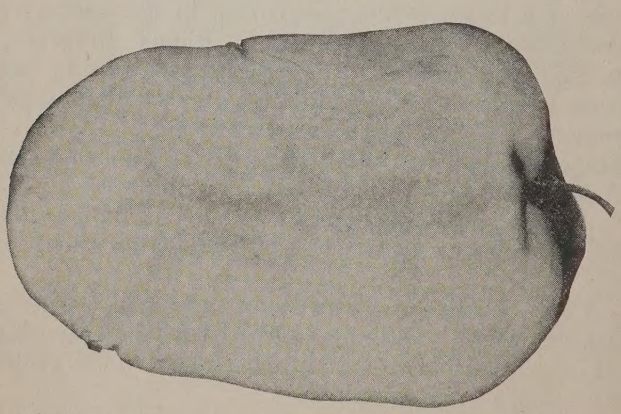

Fig. 1.—Potato wilt. Internal view of diseased potato tuber, showing stem-end discoloration, a good indication of the disease when associated with typical wilt symptoms in the field.

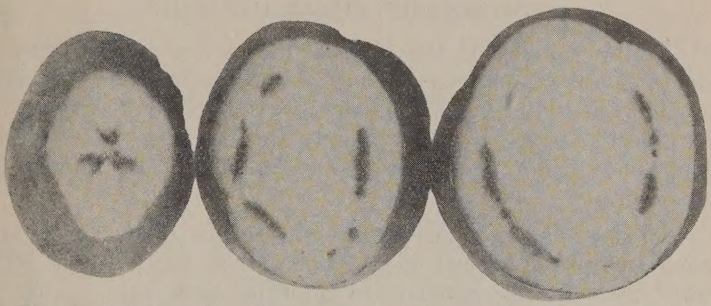

Fig. 2.—Potato wilt. Cross-section views of diseased potato tubers, showing a discolored vascular ring.

fective germination and an irregular stand of plants varying greatly in size. The absence of feeder roots is often noticeable and the stolons are cankered and weakened.

Under Montana conditions the disease is not noticeable until the plants are about one foot high, when the lower leaves lose their luster, droop, and die. This condition progresses up the stem until the entire plant dies prematurely. Usually these symptoms appear during the month of August. In moderate infections the plants die only a week or two in advance of normal maturity, while if the disease is severe the plants may be killed before the tubers are of a size suitable for market.

The lower part of the stem of the potato vine often shows a brown vascular discoloration which extends throughout the underground portions. The fungus also attacks the root system and as a result the vines are easily pulled out of the ground.

In the tuber the disease often causes a distinct browning of the vascular ring, which is very conspicuous in well-defined cases when the tuber is cut across the stem end. This symptom and its significance are discussed in detail in another section of this paper. It is from this condition that such names as "vascular discoloration," "internal browning," or "net necrosis" originated. See Figures 1 and 2.

CONTROL OF FUSARIUM WILT

In the control of this disease there are two factors of about equal importance, namely, seed selection and crop rotation, including good cultural care. Seed treatment is not effective since it will kill only the organisms on the exterior and is not injurious to the fungus in the interior of the tuber.

To decrease the amount of wilt in the potato crop, one should maintain a seed plot as described by Whipple (22). Briefly stated, this consists in planting each year a plot of ground of approximately one-tenth the total acreage devoted to raising potatoes. The seed plot should be isolated from the main crop and given special cultural care throughout the season. This plot should be planted on the tuber-unit plan, i. e., the selected tubers should be taken to the field whole and then cut as planted. When planted in this manner all the plants from a single tuber are together, which makes it easier to detect non-vigorous or diseased plants, and also any mixture of varieties.

This plot should be inspected several times during the season and all abnormal, weak, or diseased plants removed. In roguing, care should be taken always to remove all tubers on the affected plants. It is also advisable to remove one plant on each side, because the disease has a tendency to spread in the row, apparently through contact and infection of the intermingling root systems.

This plan, if followed, furnishes seed of the highest quality and, if combined with crop rotation and seed disinfection, should greatly reduce the loss from disease and increase the average yield.

Greening potatoes before planting and discarding all weak plants, judged by the vigor of the sprouts, is recommended by some investigators and has aided materially in decreasing this disease.

At the present time no varieties are immune to fusarium wilt, although some are apparently more resistant than others. In localities where the disease is destructive, the planting of early varieties is advocated as these varieties

usually mature before the disease becomes serious. Early-maturing varieties planted as soon as feasible in the spring will nearly always escape the disease, or they will become infected so late that the crop will mature with very little decrease in yield.

CAUSAL ORGANISM

Fusarium wilt has been recognized as a serious potato disease ever since Stewart (19) described it in 1895, but at that time he did not determine the cause. In 1897 he again (20) reported that the so-called "stem blight" had been destructive in 1896 and 1897.

In recent years considerable study has been devoted to this disease. The publications of Smith and Swingle (18), Orton (14, 15), Carpenter (2), Link (8), Bisby (1), Haskell (6), Goss (4, 5), and others give a very good history of the disease and the work which has been done on it.

Fusarium oxysporum Schlecht. or one of its varieties (13:258) is the cause of potato wilt. This fungus is favored by a high temperature and the disease usually appears during the hottest part of the growing season. At this time conditions are unfavorable for the host and favorable for the development of the fungus. Its temperature relations have been thoroughly investigated by Smith and Swingle (18), Link (8), and Haskell (6). These investigators vary in their results but the maximum temperature was from about 100° to 104° F. The optimum varied but averaged about 79° F. and the minimum, 41° F.

The pathogenicity of the organism has been demonstrated by artificial inoculation of stems and tubers by Link (8), Carpenter (2), Haskell (6), and Goss (5).

Most of the infection comes from the soil and this is sometimes the cause of heavy losses from this disease. The organism is quite generally distributed and occurs in virgin soil, as proved by Werkenthin (21), who says:

> Of special interest is the fact that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e. g. *Fusarium solani* (Mart) Sacc., *Fusarium oxysporum* Schlecht., and *Fusarium radicicola* Wollenweber. It also should be noted that these fungi were isolated sev-

eral times from the same plot during a period of over five months, which fact shows clearly that these fungi are true inhabitants of the soil. . . . . The present investigation proves clearly that these fungi live as saprophytes in the soil at least through the winter months, and it seems reasonable to assume that they must live saprophytically throughout the year.

Jensen (7) in his summary says:

The fungous flora of the soil is taken to consist of obligate saprophytes and facultative parasites. The former are by far the more abundant in the soil. . . . . Many facultative parasites can be directly isolated from the soil, as shown by the isolation of . . . *Fusarium oxysporum* Schlecht., *(Fusarium orthoceras* Appel) . . . by the writer.

After the disease is once established in a soil it is very persistent and may continue to live for years in the absence of a potato crop.

Evidence of infection of the crop by the use of diseased seed is fragmentary and inconclusive. Some authors report positive results, while others, working under somewhat similar conditions secured negative results. It seems plausible that environmental conditions such as soil moisture and soil temperature are important factors in the infection of the growing plant and the progress of the disease. Very little accurate data of this sort are available as in many of the reported cases meteorological and soil moisture data are wanting.

Goss (4) considered that temperatures of 64° F. and below were unfavorable for the development of the wilt disease and that in general the amount of infection increased with increasing soil temperatures. Constantly low soil moistures were unfavorable for the development of the disease. The disease developed best when the plants were started at a low soil moisture content, changed to a high soil moisture content during the critical period in the life of the plant, and later lowered to the original low soil moisture content.

Pratt (17) concluded that—

Planting clean seed potatoes on new land does not guarantee a disease-free product. A smaller percentage of disease may appear in the product when clean seed is planted on alfalfa or grain land than when similar seed is planted on virgin or raw desert land.

This indicates that virgin land is contaminated and infects the growing crop. Again, Pratt says:

All tubers showing pronounced vascular discoloration were considered as infected with wilt caused by *Fusarium* sp. Tubers showing such discoloration were taken to the Experiment Station laboratory and cultures were made from the discolored vascular tissue. Eighty per cent of all cultures showed the presence of either *F. oxysporum* or *F. radicicola.*

Goss (5) concludes from his experiments that—

Neither vascular discoloration of the tuber nor of the stem is a good index of infection with *F. oxysporum* unless these symptoms are found in connection with a wilted plant.

FUNGUS MAY CAUSE A TUBER ROT

Under conditions of very high temperature and humidity *Fusarium oxysporum* Schlecht. may cause a complete destruction of the potato tuber, as proved by the work of Link (8) and Goss (4). However, such conditions would seldom, if ever, be found in storage.

STEM-END DISCOLORATION NOT A POSITIVE CRITERION OF FUSARIUM WILT

A popular impression has prevailed that stem-end discoloration is a trustworthy criterion of fusarium wilt. Recent work, however, has proved that this discoloration may be due to *Fusarium* or other organisms or that it may arise from physiological causes.

Edson (3) proved that vascular discoloration of stem-end tissues of potato tubers was not proof of the presence of parasitic fungi. Out of 3203 examinations of tubers, 3042 of which were from discolored tissue, 1352 gave negative results.

McKay's (9) results show that—

Out of over twelve thousand tubers, from wilted and healthy hills, tested in detail during the past few years at Corvallis, Oregon, only 45 per cent of the distinctly browned tubers were as a matter of fact invaded by a wilt fungus, while the other 55 per cent were apparently free from any wilt-producing organisms, though to all appearances the tubers could not be distinguished from each other. On the other hand, not all

tubers which are invaded by a wilt fungus are discolored; 5 per cent of all the tubers examined and having no discoloration were really infected by a wilt-producing organism. This emphasizes the unreliability of depending on a bin examination of the tubers for the determination of the presence of wilt infection in seed potatoes.

Goss (5) concludes from his experiments that—

Vascular discoloration is not a good criterion of the presence of *Fusarium* unless it be produced by a wilted plant, and even then the chances are that it will not reproduce the disease the following year by means of seed infection.

This fact was brought to the attention of the writer in the fall of 1920 when a certain stock of seed potatoes was refused at point of destination because of vascular discoloration of the stem end of the tubers. A 15-pound sample of the original stock was submitted to the laboratory and cultures made from 20 tubers in the usual manner with negative results. For verification a second sample was requested and cultures made from 50 tubers; 90 per cent yielded negative results, proving beyond doubt that *Fusarium* or other fungi were not responsible for this discoloration.

The history of these potatoes revealed the fact that this field was certified, having passed two field and one bin inspection. It was found, however, that the crop was grown in a light sandy loam soil and that the end of the growing season was extremely hot and dry; in fact, because of drought and high temperature the vines ceased growth and matured nearly three weeks earlier than the normal date. Vascular discoloration was general throughout the whole crop, indicating that it was associated with environmental conditions, and when these potatoes were planted the resulting crop was normal in every respect.

Over two hundred other tubers were tested during 1920 and 1921 and less than 5 per cent proved to be infected with *Fusarium*. Most of these tubers were grown under unfavorable environmental conditions, which no doubt accounted for the discoloration of the stem end. A few of the tubers were infected with fungi other than *Fusarium* but these were not identified. Eighty-five per cent of all tubers tested were proved to be free from all organisms. Tubers with discol-

ored stem ends from vines showing characteristic wilt symptoms gave a high percentage of positive results. These tests support the view held by other investigators that vascular discoloration of tubers is not a sure indication of disease unless they originate from vines showing characteristic symptoms of the wilt disease.

EXPERIMENTS IN PLANTING INFECTED SEED

In order to determine the effect of planting inoculated seed pieces the following tests were made.

Ten freshly cut seed pieces were immersed in a youngspore suspension of *Fusarium oxysporum* var. *asclerotium* (13:358) for five minutes and planted immediately under field conditions. Similar uninoculated seed pieces were used for checks. Notes on the resulting plants were taken frequently, and no indications of wilt appeared during their life. This experiment was repeated the following season with similar results, thus indicating that seed infection is not an important factor unless environmental conditions for infection and progress of the disease are favorable.

In another test ten tubers weighing about four ounces each were inoculated with the organism and were incubated in the laboratory until each tuber showed distinct symptoms of infection, when they were planted in the field. Similar uninoculated tubers were used as checks. No wilt developed in any of the resulting plants. This experiment was repeated and the results were verified the following season.

These experiments and the results of other investigators indicate that the use of infected seed does not necessarily mean a seriously diseased condition in the resulting crop. However, the use of infected seed is not advocated, because it infects the soil in proportion to the amount of disease that is introduced with the seed, and seasons occur when environmental conditions are very favorable for the development of the disease with resulting severe losses. Environmental conditions are perhaps the most important factor in the occurrence and severity of the disease.

Crop rotation and the planting of disease-free seed are recommended to keep soil infection to a minimum, in order to lessen the chances of infection of the succeeding crop. The more soil infection the greater is the danger of loss from this disease when conditions are favorable for its development.

SUMMARY

Fusarium wilt occurs generally within the United States wherever potatoes are grown.

The losses vary with the severity and time of infection and the variety of potato, often amounting to as high as 30 per cent of the crop.

Briefly described, the symptoms are yellowing and curling of the older leaves, progressing up the stem, wilting of the entire plant, and finally premature death of the plant and decay of the roots.

Vascular discoloration of the stem end of tubers is not a sure indication of the presence of *Fusarium* unless associated with typical wilt symptoms in the field.

The principal source of the disease is the soil as the fungus can live for several years in the absence of potatoes.

The disease is severe under environmental conditions favorable for infection and progress. Wilt is favored by high temperature and moisture, but after infection symptoms appear earlier under drought conditions.

The disease is caused by *Fusarium oxysporum* Schlecht. or one of its varieties.

Seed disinfection will not control the disease. A seed plot should be maintained to secure seed of high quality. Crop rotation is advisable.

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